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Procedia Earth and Planetary Science 7 (2013) 451 – 454

Procedia
Earth and Planetary Science

Water Rock Interaction [WRI 14]

Stable isotope composition of surface and groundwater in Baja California, Mexico

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Abstract

Based on a total of 135 stable isotope analysis ($\delta^{18}O$, δD) carried out on surface and groundwater samples, as well as on rainwater samples between 2004 and 2011 in 5 different regions in Baja California, an isotopic evaluation of the region was established. The results showed a depletion gradient of -0.25 ‰ $\delta^{18}O$ per 100 m rise in elevation throughout the study area. Considering an unaltered $\delta^{18}O$ signature for the thermal springs, the recharge areas of these waters are at elevations over 1400 m outside of the present watersheds, indicating the presence of regional flow systems next to the local flow regime feeding the cold springs and wells. The Mesa de Andrade area has a completely different signature with values of -105 for $\delta^{18}O$ and -13 for δD.

Keywords: stable isotopes, Baja California, groundwater.

1. Introduction

In most low-temperature environments, stable hydrogen and oxygen isotopes behave conservatively through a catchment [1]. The main processes that influence the isotopic compositions of waters in a catchment are phase changes like evaporation or condensation in the atmosphere, and simple mixing at or below the ground surface. Stable oxygen and hydrogen isotopes can be used to determine the contributions of old and new water to a stream during periods of high runoff because the rain that triggers the runoff is often isotopically different from the water already in the catchment [1]. The semi-arid to arid climatic conditions of Northern Baja California shows a low intensity predominantly winter precipitation. Furthermore the geological setting is relatively homogeneous. These settings allow by comparing the oxygen and hydrogen stable isotope composition throughout this relatively large area to determine regional characteristics and distribution of the isotopic signatures.

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doi:10.1016/j.proeps.2013.03.194

1.1. Study area

The study area can be divided into five regions spreading throughout most of the northern section of Baja California (Fig.1). Region 1 consists in 11 well samples and 5 high saline surface water samples from temporal lagoons with elevations ranging from sea level to up to 70 m. The Guadalupe Valley (region 2) has total of 72 groundwater samples taken from springs and wells with elevations ranging from 300 m to 900 m. Furthermore one thermal spring and one surface water sample were analyzed. Region 3 comprises a total of 11 well and spring water, 5 surface water, 3 thermal spring water and one rainwater sample with elevations for the sampling sites ranging between 300 and 1100 m. The forth region includes a total of 9 well water and one thermal water samples and is located in the southern parts of Baja California state. The elevations of these sample sites range between 100 and 1100 m (Fig. 1). Region 5 is located at the border to the United States near the city of Mexicali and consists in 2 water samples from piezometers (elev. 28 m) upstream of wetlands formed by seepage form the All American Canal as well as 4 wetland samples and 5 samples from drainage ditches diverting the seepage [2].

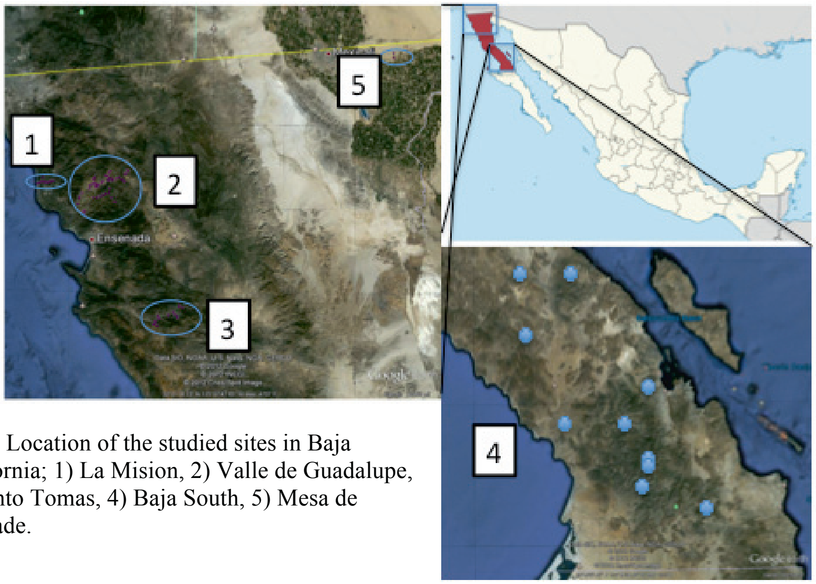

Fig 1: Location of the studied sites in Baja California; 1) La Mision, 2) Valle de Guadalupe, 3) Santo Tomas, 4) Baja South, 5) Mesa de Andrade.

1.2. Hydrogeology

Groundwater recharge occurs in Baja California mainly through Mountain-Block-Recharge (MBR) and Mountain-Front-Recharge (MFR) in the higher elevations of the mountain ranges around the Sierra de Juarez and Sierra de San Pedro Martir [3]. MBR und MFR includes most of the water, which reaches a valley aquifer and has its origin in the surrounding mountain ranges. This type of groundwater recharge is characteristic for valley aquifers in mountainous watersheds in arid and semiarid regions [4]. The quantity of faults and factures present in the area furthermore favors recharge.

1.3. Climate

The climate of Baja California is for the northern sections characterized by winter precipitation of low intensity from October to March with average precipitation for the Northern parts (regions 1-3) of around 250 mm/y and around 110 mm/y in region 4. The average temperatures from the 1980-2004 time period range between 12.3 °C in January and 26 °C in August. The more southern and eastern weather stations in region 5 in Baja California also show the influence of the summer monsoon, which results in precipitation events during the summer period of July to September and originating in the Gulf of California [5].

2. Methods and Sampling

The stable isotope samples were taken during several sampling periods from 2004 to 2011 and include a total of 105 groundwater and spring samples, 6 thermal springs, 11 surface water samples as well as 2 groundwater, 5 drains and 4 pond samples for the Mesa de Andrade area. Furthermore one rainwater sample was analyzed for the Santo Tomas watershed. All stable isotope samples were analyzed at the Environmental Isotope Laboratory of the Department of Geosciences at the University of Arizona using an Isotope Ratio Mass Spectrometry (IRMS) in comparison to the Vienna Standard Mean Ocean Water (VSMOW). The δD values show a standard deviation (σ) of 0.8. The $\delta^{18}O$ standard deviations varied between 0.08 and 0.11.

3. Results and discussion

The stable isotope composition of the samples shows significant variations in its isotopic signature partly depending on the type of water analyzed. The spring and well samples show values ranging for $\delta^{18}O$ between -5.0 and -7.0 and for δD between -31 and -45 for most of samples in the study areas 1 to 3. The surface water samples for these areas show comparable values except the high saline lagoons in area 1, which are depleted in $\delta^{18}O$ due to evaporation effects. Thermal springs and wells located in the areas 3 and 4 show a slightly different composition compared to the well samples with values of around -8.2 for $\delta^{18}O$ and -53 for δD respectively. Study area 4, the Southern section of Baja California State shows for some samples an increased evaporation effect probably due to the higher temperatures and lesser precipitation in the area (Fig.2). The rainwater sampled during a storm event in the Santo Tomas watershed shows an isotopic signature of -4.2 $\delta^{18}O$ and -19 δD, which are values similar to data reported form other location with similar climatic characteristics. Nevertheless more rainwater samples will be necessary to be able to identify the isotopic variations for the study area.

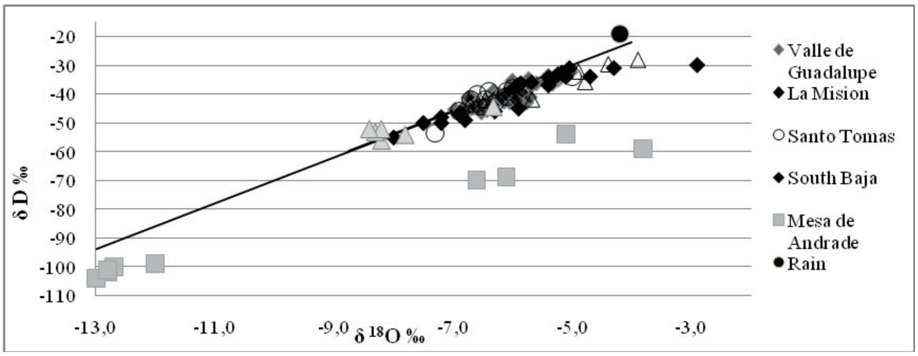

Fig. 2: $\delta^{18}O$ vs δD correlation for water samples in the study area.

A different stable isotope signature can be found in the samples from the Mesa de Andrade showing the most depleted ground water samples with $\delta^{18}O$ values of around -105 and δD of -13. The adjacent wetlands differ significantly from these values ($\delta^{18}O$ -6.6, δD -70) indicating strong evaporation effects (Fig. 2).

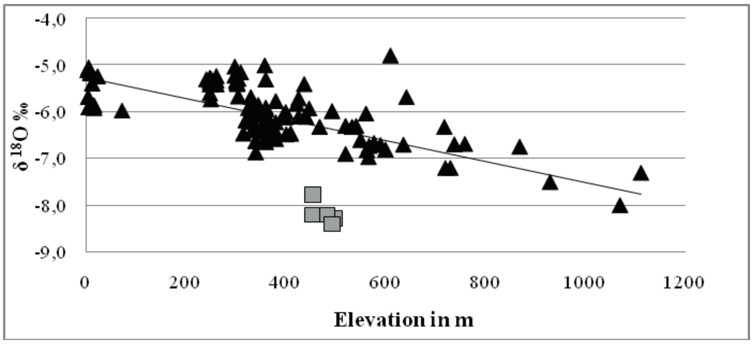

Fig 3: $\delta^{18}O$ vs elevation correlation ▲ wells and springs, ▢ thermal water.

Considering that most of the wells and springs are fed by local recharge and are therefore reflecting relatively unaltered present precipitation it is possible to demonstrate the elevation effect of the isotope fractionation processes [3]. In Fig. 3 a depletion gradient of -0.25 ‰ $\delta^{18}O$ per 100 m rise in elevation is visible. The thermal springs were not included in the calculation of this gradient, but considering an unaltered $\delta^{18}O$ signature, the recharge area of these waters would be at elevations of over 1400 m and outside the present watersheds indicating regional flow systems.

4. Conclusions

The stable isotope composition for the ground and surface water samples of Baja California shows a relatively homogeneous isotopic signature (except Mesa de Andrade) with an elevation effect of -0.25 ‰ $\delta^{18}O$ per 100 m rise in elevation. The thermal waters indicate next to the local flow system in the watersheds also the presence regional water flow. Furthermore the arid environment is reflected in the existence of evaporation trends found in surface water as well as several well water samples.

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